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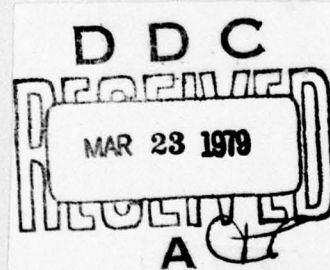
FOREIGN TECHNOLOGY DIVISION

INVESTIGATION OF EXCHANGE BETWEEN RECIRCULATION ZONE
BEHIND STABILIZER AND EXTERNAL FLOW AND SOME
PROBLEMS OF FLAME STABILIZATION

By

T. A. Bovina

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SOME PROBLEMS OF FLAME STABILIZATION

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yë or ë.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

INVESTIGATION OF EXCHANGE BETWEEN RECIRCULATION ZONE BEHIND
STABILIZER AND EXTERNAL FLOW AND SOME PROBLEMS OF FLAME STABILIZATION

T. A. Bovina

INTRODUCTION

We know that combustion stability when a flame is stabilized by
means of poorly streamlined bodies is achieved by continuous ignition
of the fuel mixture of combustion products from the recirculation
zone formed behind the body. However, the specific mechanism of this
ignition and the phenomena of flameout have not yet been thoroughly
studied. Some researchers (see, for example [1], and [2]) believe
that combustion stability behind the stabilizer is determined solely

by the thermal state of the zone of reverse currents. It is also
believed that the relationship between the time that the mixture
remains in the zone behind the stabilizer and its combustion time
determines the stability of the combustion process. These theories do
not, however, address the problem of the place of ignition of the
fresh mixture behind the stabilizer and are not confirmed by
experimental temperature measurements in the zone. Evidently it would
be better to study the phenomenon of stabilization not from the
standpoint of balance in the zone, but from the standpoint of the
heat balance which is external with respect to the zone, since the
amount of heat carried into the external flow determines the course
of development in it of the chemical reaction which occurs under
certain conditions prior to ignition.

Thus, from our standpoint, the stability of the process depends
not only on the ignition source, but also on external conditions,
i.e., on the amount of heat received by the fresh mixture and, in
this connection, the manner in which the chemical processes develop
in it.

Thus, it is best to begin our study of the stabilizer with the
patterns of heat exchange between the recirculation zone and the
external flow.

STUDY OF MASS EXCHANGE BEHIND THE STABILIZER

Based on the peculiarities of the flow behind a poorly streamlined body, we assume that the exchange between the zone and the flow occurs primarily as a result of turbulent diffusion.

We also assume that the relationship between the diffusion coefficient of the zone D_Q and the diffusion coefficient of the oncoming flow D_n, flow velocity v_n, and the dimension of the stabilizer d_{cT} is achieved in the form of a simple dependence

(1) $$\frac{D_{\text{в}}}{v_{\text{в}}} = k_1 \frac{D_{\text{в}}}{v_{\text{в}}} + k_2 d_{\text{ст}},$$

which satisfies the boundary conditions.

Here k_1 and k_2 are the coefficients of proportionality.

This dependence was later verified experimentally.

For the recirculation zone we found no method of directly determining the coefficient of turbulent exchange. However, it can be indirectly determined by the magnitude of the average time that the

gas remains in the zone behind the stabilizer.

The average time (average time of exchange) τ_n is determined as the ratio of the volume of the zone to the volume flow of gas through it.

In the case of diffusive exchange

(2) $\tau_n = \dfrac{V_0 r_{cp}}{S_0 D_0}.$

where V_0, S_0 and r_{cp} —represent the volume, surface, and average radius of the zone, respectively.

If we know the average time and the dimensions of the zone, then from this formula we can calculate the average coefficient of diffusion*.

[FOOTNOTE: The value D_0 was assumed to be average for the entire zone. The corresponding coefficient of proportionality in equality (2) was included in the value r_{cp}. END FOOTNOTE]

Determination of the average time was a problem of independent and more general interest*.

[FOOTNOTE: Recently we became aware of study [3], in which the exchange behind a stabilizer is also studied and a method is proposed for determining the time that the cold currents remain, which does not differ basically from the method described here. Only one value for this time is given, namely, for a conical stabilizer 64 mm in diameter at a flow speed of 3.8 m/s. The shape of the stabilizer and its flow conditions do differ from ours. END FOOTNOTE]

The method of experimentally determining τ_n was as follows. A secondary mixture, easily carried along by the turbulent movements of the medium and whose presence could be established in some way, was introduced into the zone behind the stabilizer. After the stationary process between the entry and removal of the mixture was established, the supply of it was cut off abruptly and the time change in its concentration from equilibrium to zero observed. In this case the change in concentration should be subject to the following law:

(3) $C = C_0 e^{-\frac{t}{\tau_0}}$,

where C_0 is the concentration of the mixture at the initial moment in

time, i.e., at the moment that its supply to the zone ceases;

τ_η - the constant coefficient for the exponent - time during
which the concentration of the mixture decreases e times. Numerically
this quantity is equal to the average time that the gas remains in
the recirculation zone during the stationary process. If we determine
it from equation (3), then we get the value for the average time.

In practice the value τ_η was found as follows. In working with
cold currents, tobacco smoke was introduced into the zone behind the
stabilizer. Portions of this smoke were capable of reflecting the
light incident on them. During combustion an aqueous solution of
common salt was injected into the zone. In the hot zone the water
evaporated, and the sodium vapor which was formed radiated the
light*.

[FOOTNOTE: It was experimentally confirmed that the amount of
injected water and its time of evaporation have no substantial effect
on the thermal regime of the zone or the radiation of the sodium
vapors. END FOOTNOTE]

The light reflected or radiated by the particles was captured by

a photomultiplier, and the developed current was amplified and transmitted to an oscillograph for notation. The work was conducted in the region proportional to the dependence of radiation on the concentration of particles. The dependence of the current strength (voltage) on time, according to our estimation, should be exponential when the glowing particles enter the zone - curve ab, and when they are carried out - curve bc (Fig. 1a). Yet, since we used an ac amplifier*, at the amplifier output, i.e., at the oscillograph input, the change in the strength of the current in time should be as follows:

$$(4) \qquad I = \frac{U_0}{R}\left(e^{-\frac{t}{\tau_n}} - e^{-\frac{t}{\tau_c}}\right)\frac{1}{\left(\frac{\tau_n}{\tau_c}-1\right)},$$

where U_0 is the voltage corresponding to current I_0; R - resistance of circuit and shunts; τ_c - time constant of circuit.

[FOOTNOTE: Selection of the ac amplifier is explained by a number of its advantages as compared to the dc amplifier, both with respect to the simplicity of the circuit and work stability and greater accuracy in determining τ_n with the aid of oscillograms. END FOOTNOTE]

The oscillograms took a form similar to the curves shown in Fig. 1b.

For convenience in determining r_n from these curves we obtain the relationship between the time corresponding to the maximal point on curve r_{max} (points b and e in Fig. 1b), the time constant of the circuit, and the time spent [in the zone]

$$(5) \quad \tau_{max} = \frac{\ln \tau_c - \ln \tau_s}{\frac{1}{\tau_s} - \frac{1}{\tau_c}}.$$

Dependence $\tau_s = f(\tau_{max})$ when $\tau_c = const$ plotted in the form of a curve, which was used in determining r_n.

The calculated values of the change in the strength (voltage) of the current in time were compared with experimental values taken from the oscillograms (Fig. 2). There is an amazing coincidence between the experiment and the calculation, leading to the deduction that, as assumed, the change in the concentration of glowing particles in the zone does follow the law of (3) and that the obtained formula (5) is suitable for determining r_n.

The accuracy of determining τ_η by the given method was $\pm 7-8^0/_0$.

The work was conducted in a chamber of rectangular section of 90 x 180 mm. Stabilizers (V-shaped), from 20 to 60 mm in dimension with an apex angle of 30^0, were installed at a distance of 250 mm from the edge of the chamber (see the scheme in Fig. 3). The speed of the flow varied from 10 to 70 m/s for cold injections and from 60 to 160 m/s during combustion.

The turbulence intensity of the flow varied from 5 to $20^0/_0$. The excess air ratio α - from 0.8 to 1.45.

Homogeneous gas-air mixtures were used.

In each regime 10-15 photos were taken. After these were processed, the average of τ_η was found.

From general concepts of diffusion exchange we might expect the following dependences of τ_η on the dimension of the stabilizer and the speed in turbulence of the oncoming flow. With a change in the stabilizer dimension r_{cp} and ratio $\frac{V_1}{S_1}$ in equation (2) change in proportion to d_{cr}. Then, τ_η should be proportional to $\frac{d_{cr}^2}{D_0} \sim \frac{d_{cr}^2}{K_1 + K_2 d_{cr}}$,

where K_1' and K_2'' are constant.

Or, if K^6 can be ignored, then τ_{η} can change in proportion to d_{cT}.

We know that in technical tubes the value $\frac{D_0}{\tau_n}$ remains constant when the speed of the flow changes (self-similar theory). Then, as follows from (1), quantity $\frac{D_0}{\tau_n}$ should also remain constant

$$\frac{D_0}{\tau_n} = \frac{V_0 \tau_{cp}}{S_0 \cdot \tau_0 \cdot \tau_n} = \text{const.}$$

Since we know that the dimensions of the zone remain virtually unchanged with velocity, then τ_{η} should change in reverse proportion to the velocity of the flow.

When a turbulizing grid is placed in the flow, the diffusion coefficient of the flow increases. With an increase in the distance from the grid the intensity of the turbulence falls, while scale l_0 increases. Yet, since in this case the decrease in intensity is more abrupt than the increase in scale, the value $\frac{D_0}{\tau_n} = d_0$ should decline as the distance from the grid increases. We might expect that $\frac{D_0}{\tau_n}$ will in this case decrease linearly, while τ_{η} will increase in the same ratio.

Presented in Fig. 4 for the case of a cold flow when d_{cT} = 50 mm

are the experimental dependences of τ_n on the stabilizer dimension and the speed and turbulence intensity of the oncoming flow, along with the change in τ_n along the zone.

As we see from these curves, the obtained results do agree with the theoretical premises. *For tubular (~5%) turbulence it can be considered that*

$$\tau_n \simeq 37 \frac{d_{cr}}{v_n} \, s.$$

From the experimental values of τ_n at different $\frac{D_s}{v_s}$, and at constant $\frac{D_s}{v_s}$ and different stabilizer dimensions the values of the average diffusion coefficient (D_g) in the recirculation zone were calculated.

The experimental data are approximated by equation (1) at values of constants $K_1 = 1$ and $K_2 = 0.004$ (see Fig. 5).

From equation (1) we see that when $d_{cr} \rightarrow 0 \quad \frac{D_s}{v_s} \rightarrow \frac{D_s}{v_s}$.

The value of $\frac{D_s}{v_s}$ for the smallest stabilizer $d_{cT} = 20$ mm was equal to 0.13 mm, while the value of $\frac{D_s}{v_s}$, determined by the optical-diffusion method, was equal to 0.12 mm*.

[FOOTNOTE: Optical-diffusion method described in more detail in [4]. END FOOTNOTE]

Such close values seem to indicate the correctness of determining D_3 and τ_n. Evidence of this can also be found in the fact that the values of D_3 which are indirectly determined through τ_A were close to the values of the diffusion coefficient in the mixing zone, which were determined by means of the optical-diffusion method*.

[FOOTNOTE: The thin tube through which the smoke was admitted was placed on the edge of the stabilizer. With the aid of photography and subsequent processing (assuming that the values of the pulsations were the same in the direction of both axes), the value of the diffusion coefficient in the mixing zone was determined. END FOOTNOTE]

These values (d_{cr} = 50 mm) are presented in Table 1.

The results of the experiments conducted during combustion are shown in Fig. 6. We learn that during combustion in a flow with tubular turbulence τ_n can be expressed by the dependence

$$\tau_n \simeq 104\frac{L}{v_n}, \; s,$$

The time that the turbulent flow remains [in the zone] during combustion is 3.7 times greater than in the case of the cold flow. This is apparently explained by a decrease in the total level of turbulence in the combustion zone, indirectly indicated by decrease in the gradient of average velocities behind the stabilizer. Just as in the case of cold flows, τ_Π decreases as the turbulence of the oncoming flow increases (Fig. 6b). In a range of change in α of from 0.8 to 1.45 (Fig. 6c) the time [that it remains in the zone] remains virtually constant, apparently explained by the very slight change in the diffusion coefficient in the given range of α.

INVESTIGATION OF STABILIZATION MECHANISM

As indicated, the change in the concentration of glowing particles in the zone occurs according to the law of (3), i.e., equation $\frac{dc}{dt} = -\frac{1}{\tau_s} s$ is correct for the speed of change in the concentration. It is obvious that by analogy to the processes of mass and heat exchange, the following equation will be correct for the speed of heat exchange

$$\frac{dq}{dt} = -\frac{1}{\tau_s} (\gamma C_p T - \gamma_s C_{ps} T_s).$$

where γ, C_{ρ}, T represent specific weight, heat capacity, and temperature of the gases in the zone, respectively; $\gamma_{\nu}C_{\rho_{\nu}}T_{\circ}$— represent the values of the same parameters in the oncoming flow.

To determine the amount of heat which is removed from the zone to the external flow temperature, measurements were taken in the zone in steady regimes, regimes close to flameout, and at the moment of flameout. The measurements were taken by chemical analysis and with the aid of a thermocouple*.

[FOOTNOTE: All temperature measurements were taken in the region bounded by the surface of the zero horizontal velocities in the so called zone of "reverse currents." The boundaries of this zone, unlike the recirculation zone, are easily determined experimentally. END FOOTNOTE]

The graphics (Fig. 7) show the dependence of the completness of combustion ϕ, measured by chemical analysis, on the excess air ratio for different flow speeds and stabilizer dimensions.

The measurements show that combustion completeness in the zone is sufficiently high - ϕ_{cp} = 0.96—0.97 - and that it does not change

as flameout approaches, either with respect to α or with respect to v_n, up to regimes which are rather close to flameout ($\alpha = 0.9\,\alpha_{c\rho}$). This indicates that the temperature in the zone is close to the theoretical combustion temperature for the given α.

In Fig. 8 we see the temperature field over the section of the zone, measured by the thermocouple.

The upper half of the diagram corresponds to the regime of $\alpha = 1.56$; $v_n = 143$ m/s ($t_{c\rho} = 1360°C$); the lower half corresponds to approximately the same regime of $\alpha = 1.58$, although to a velocity which is 1.5 times lower - $v_n = 90$ m/s ($t_{c\rho} = 1355°C$). These measurements, as we see from the diagram, also indicated that a change in velocity did not lead to a change in the average temperature in the zone.

Temperature measurements at the moment of flameout were taken with the aid of a thermocouple, which was placed in the center of the zone. The readings from the thermocouple and the flameout indicator were recorded on film. Deciphering of the film revealed that the temperature in the center of the zone, in the case of a constant value of α and an increase in v_n, remains constant right up to flameout, i.e., the beginning of the avalanche-like temperature drop in the zone. The flame, according to the indicator, is completely

extinguished within 0.02-0.05 s.

Thus, the obtained results indicate that the zone of reverse
currents is filled with products of complete combustion, and,
consequently, flameout is not related to the insufficient time that
gases remain in the zone of reverse current, as believed by certain
researchers.

If we investigate the movement along the recirculation zone of
an element of the hot mixture and its exchange with the zone and the
external current, then we might assume that the determining factors
in the stabilization process are the amount of heat arriving per unit
volume of the fresh mixture and the time of movement of the mixture
along the service of the zone. The obtained experimental data on the
exchange and temperature in the zone, along with data on the change
in width of the mixing region, i.e., the region of heat diffusion
behind the stabilizer, made it possible to qualitatively examine the
change in the amount of heat arriving per unit volume of the fresh
mixture as the working mode of the stabilizer changed and, in
connection with it, the movement of the point representing the
beginning of combustion of the fresh mixture in relation to the
surface of the zone. It was found that the distance from the edge of
the stabilizer to the beginning of the flame l should be
proportional to the speed of the flow and time required to prepare

the mixture for combustion, conditionally called induction time τ_{η}

(6) $l \sim v_a \tau_\eta$

This time includes such components as the time required to heat the
cold mixture in the separated volume by mixing τ_{CM}, and the time
required to develop the reactions. This last time depends on the
kinetics i.e., the induction time as understood in the theory of
combustion of homogeneous gas mixtures $\tau_{\eta K}$.

We can assume that if the time of contact of the combustible
mixture with the surface of the zone τ_K becomes greater than the
preparation time of the mixture for combustion τ_η, then normal work
of the stabilizer will be impossible.

Actually, if an element of the combustible mixture moving along
the hot surface of the zone, has not managed to ignite, then, as it
crosses the limit, it is even less likely to ignite, since its
temperature begins to fall, while τ_η as a result of this
progressively increases. Then the condition for the cessation of
flame propagation into the fresh mixture can be represented by
equation (6), while the value of l is equal to the length of the
zone of reverse currents L_3, which in our case equals 3.5 d $_{cT}$

(7) $L_3^2 \sim w \cdot r_0$

   To check this hypothesis on the movement of the origin of the
flame relative to the zone of reverse currents, measurements of the
positions of the flame boundaries were taken for different working
regimes of the stabilizer. The measurements were taken by an
ionization sensor. It was found that the beginning point of
combustion of the fresh mixture moves away from the edge of the
stabilizer as the mixture is depleted and the velocity of the
oncoming flow increases. In regimes which are close to flameout,
combustion begins at a significant distance from the stabilizer, at
the end of the reverse current zone. This can be illustrated by the
following diagrams. In Figs. 9a, b, and c the distance along the tube
radius lies on the Y-axis, the distance along the reverse current
zone - along the X-axis. Points correspond to the beginning of the
chemical conversions - the flame front boundary.

   From these diagrams it is apparent that as the mixture becomes
depleted, the origin of flame expansion moves away from the edge of
the stabilizer. Measuring the distances to the point of the origin of
expansion of the flame showed that l changes in proportion to the
velocity of the flow and is exponentially dependent on the
temperature which corresponds to the given α value of the mixture.

We can assume that as a result of the intensive exchange, the mixing time is small as compared to the kinetic time of induction.

Then, according to (6), since $\tau_{mx} \sim l/u_nRT$,

$$l \sim u_n e^{\frac{E}{RT}},$$

where E is activation energy, R - the gas constant, T - reaction temperature.

Hence it follows that the results of the experiments in coordinates $\ln\frac{l}{u_n}$ and $\frac{1}{RT}$ should lie along a straight line with an angle of slope whose tangent equals E.

When the results of the experiment were processed, it was found that for all measured values of l , the point at these coordinates are grouped near a straight line (see Fig. 10). The points corresponding to flameout regimes lie along this straight line, if the values of $\ln\frac{L}{u_o}$,lie along the Y-axis, where u_o is the speed of flameout (see Fig. 11).

Thus, processing of the results of the experiment showed that apparently the factors which depend on kinetics have a greater significance in this process than mixing factors. Hence we might conclude that to expand stabilization limits we must select fuels

which with equal heat-producing capacities have lower values τ_{zr}. A preliminary decrease in this time for the fuel should also cause stability to improve.

CONCLUSION

Developed in the present study is a method for experimentally determining the time that the gas remains in the recirculation zone behind the stabilizer for cold currents and during combustion.

The method is based on the introduction into the zone of glowing particles and their photoelectric registration. The accuracy of determining this time is from ± 7 to $\pm 8 \%$.

Quantitative data on this time and on the coefficient of diffusion for the recirculation zone were obtained.

The temperatures and completeness of combustion were measured in the zone behind the stabilizer. The measurements revealed that the zone of reverse currents is filled with the products of total combustion ($\phi = 0.96-0.97$). The completeness of combustion does not decrease as we approach flameout, either with respect to the velocity or the composition of the mixture (in the direction of depletion),

i.e., the temperature of the gases in the zcne is close to the
theoretical combustion temperature for the given α.

It was experimentally established that with depletion of the
mixture and an increase in the velocity of the oncoming flow, the
point representing the origin of combustion of the fresh mixture
moves away from the edge of the stabilizer. This movement in the
origin of the flame is proportional to the velocity of the flow and
is exponentially dependent on the temperature which corresponds to
the combustion temperature for the given α of the mixture.

Proposed here is a system for explaining the mechanism of flame
stabilization behind a poorly streamlined body, according to which
the determining factor in the stabilization process is the
relationship between the time necessary for preparation for the
mixture for combustion and the time of contact between the fuel
mixture and the surface of the zone. Processing of experimental data
shows that the factors which affect the kinetics of the process
apparently play the predominant role in the total time of preparation
of the mixture for combustion.

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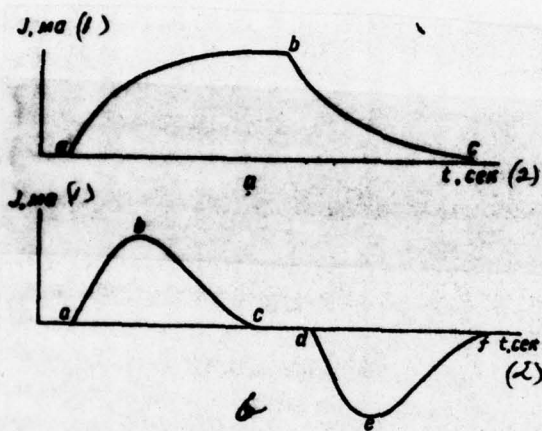   ности воздушных потоков и пламен. Дисс. М., 1956.

Fig. 1. System of change in current force in time. a - dc amplifier;
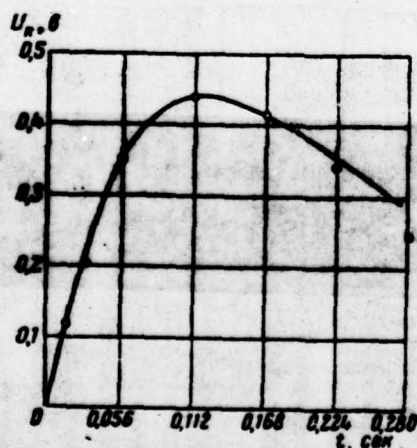b - ac amplifier. KEY: (1) mA, (2) t, s.

Fig. 2. See following page.

Fig. 2. Comparison of calculating curve V   = f(t) with experimental
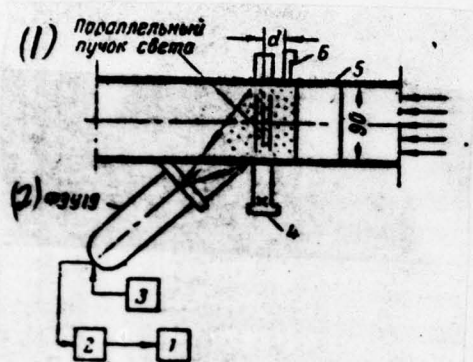data. KEY: (1) V, (2), t, s.

Fig. 3. Scheme of working chamber and block diagram of equipment. 1 -
loop oscillograph, (2) amplifier of photoelectric multiplier (UFU),
(3) supply block of photoelectric multiplier, (4) light, (5)
stabilizer, (6) valve. KEY: (1) Parallel light beam, (2)
Photoelectric multiplier 19.
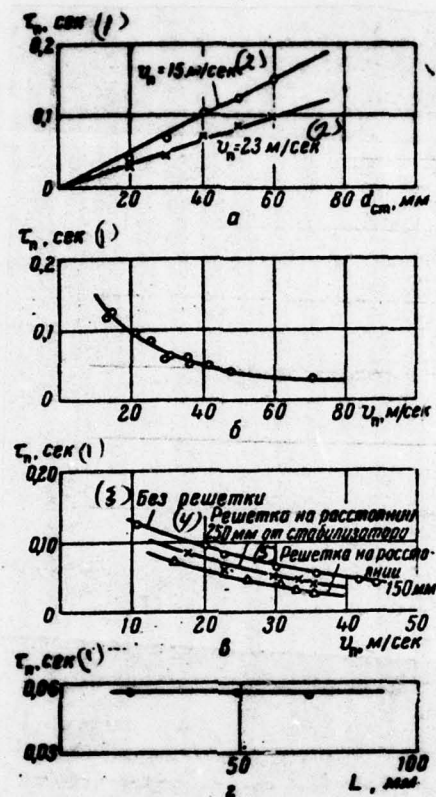
Fig. 4. Dependence of τ on stabilizer dimension (a), speed of flow
v (b), intensity of turbulence (c), distance to stabilizer (d)
(experiments with cold flows). KEY: (1) s, (2) m/s, (3) Without grid,
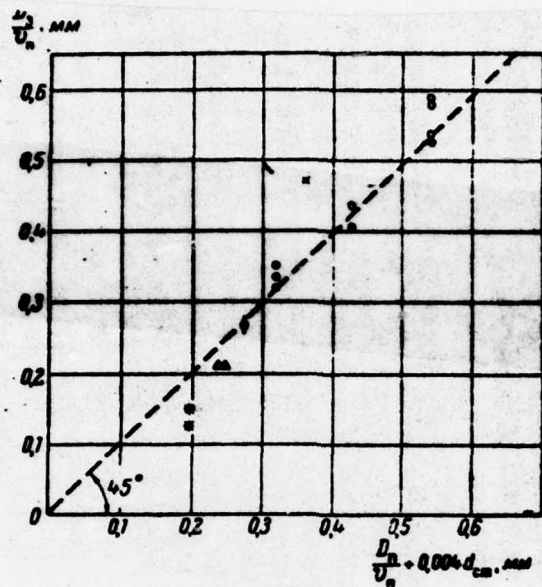(4) Grid at distance of 250 mm from stabilizer, (5) Grid at distance
of 150 mm.

Fig. 5. Dependence of diffusion coefficient of zone on flow

parameters (D_s, v_s) and stabilizer dimension $(d_{cт})$

$z - d_{cт} = 60\ мм;\ \bullet - d_{cт} = 50\ мм;\ \phi - d_{cт} = 40\ мм;$
$\triangle - d_{cт} = 30\ мм;\ * - d_{cт} = 20\ мм$

Table 1.

$\dfrac{D_{п}}{v_{п}}, мм$	$v_{п}, м/сек$ (1)	$\dfrac{D_{2}}{v_{s}}, мм.°$	$\dfrac{D_{2}}{v_{s}}, мм\ ∞∞$
0,12	44	0,35	
	30	0,33	0,2 + 0,25
	22	0,341	
0,25	35,1	0,433	
	29,8	0,444	0,35 + 0,4
	18	0,442	
0,32	35,1	0,627	
	33	0,652	0,55 + 0,6
	15,7	0,584	

(2)° По формуле (2).
(3)°° По диффузионному методу.

Key on following page.

KEY: (1) m/s, (2) According to formula (2), (3) By diffusion method.

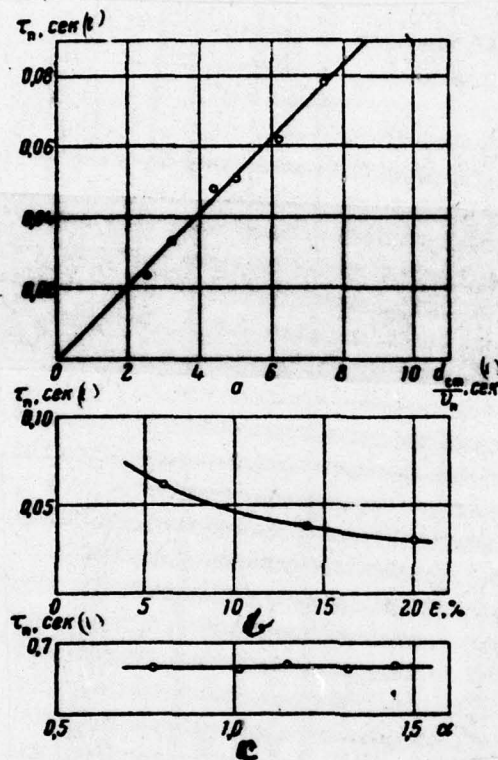
Fig. 6. Dependence of τ_q on ratio of stabilizer dimension to velocity of flow (a), intensity of turbulence (b), excess air ratio (c) (experiment during combustion). KEY: (1) s.
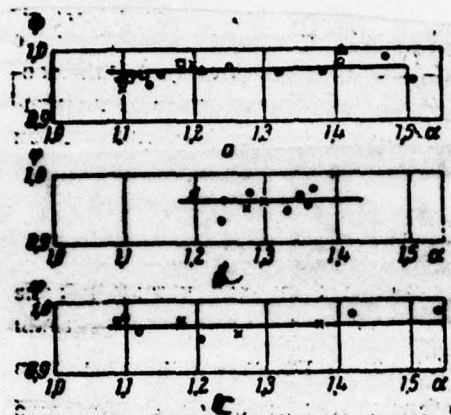
Fig. 7. Dependence of completeness of combustion ϕ on excess air ratio α for different velocities of oncoming flow (from data of chemical analysis). a - stabilizer with d = 50 mm, $\bullet$ - 83.3, x - 112, $\circ$ - 152.7, Δ - 87, $\square$ - v_Π = 149 m/s; b - stabilizer with d = 20 mm, $\bullet$ - 76, x - 118, $\circ$ - 107, $\circ'$ - v = 130.4 m/s; c - stabilizer conical with section of 60 mm; $\bullet$ - 83, x125, o - v_Π = 157.5 m/s.
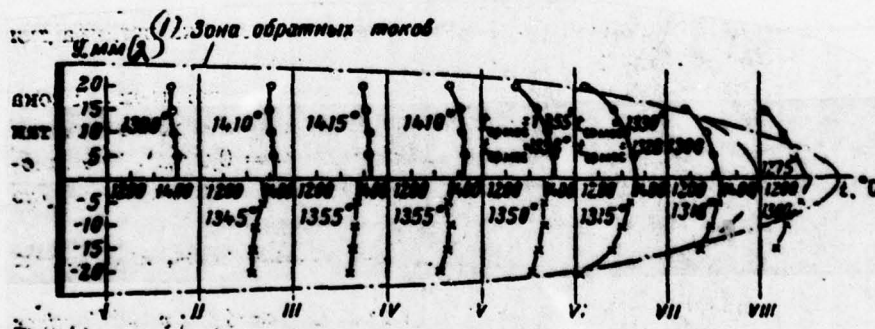

Fig. 8. Field of mean temperatures over section of reverse current zone, measured by thermocouple. KEY: (1) zone of reverse currents, (2) Length, mm.
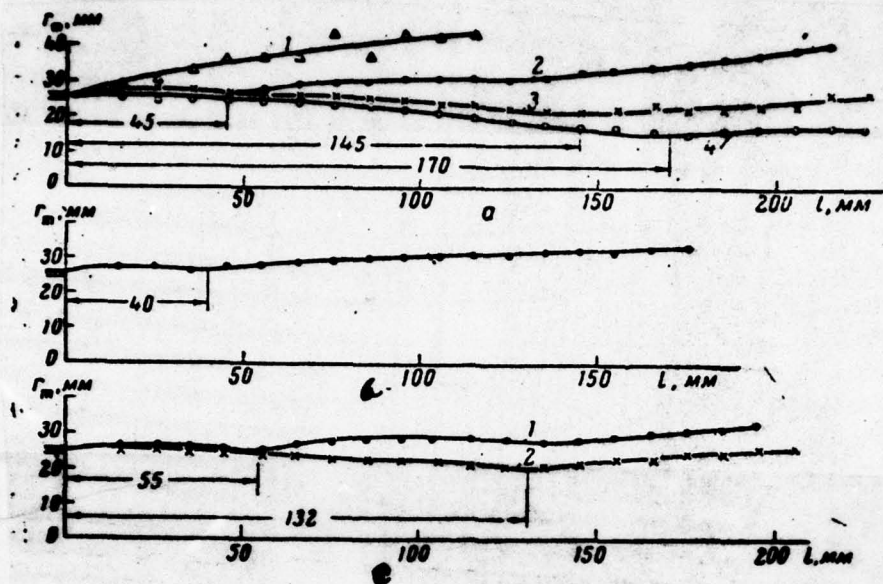
Fig. 9. Boundaries of flame front behind stabilizer, measured by ionization sensor a - for values: 1 - α = 0.9, V_Π = 82.54, m/s; 2 - α = 1.427, V_Π = 80.2 m/s; 3 - α = 1.68, V_Π = 81.3 m/s; 4 - α = 1.72, V_Π = 78.8 m/s; b - for values α - 1.375, V_Π = 80.3 m/s; c) for value 1 - α = 1.52, V_Π = 61.5 m/s; 2 - α - 1.58, V_Π = 161 m/s.
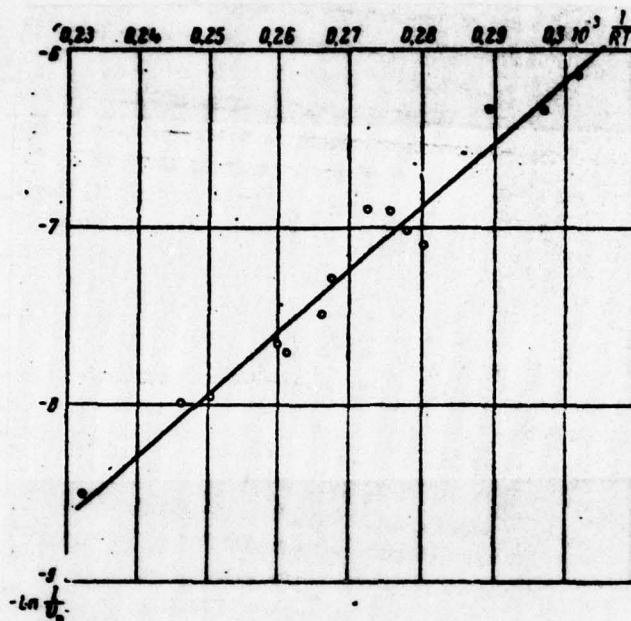
Fig. 10. Dependence of distance l from edge of stabilizer to place where flame expands in different operating modes of stabilizer. E = 35.5 Ccal/mole, $r \approx 5.62 \cdot 10^{-4}$ s, $\frac{l}{v_n} \approx 5.62 \cdot 10^{-4} e^{\frac{35500}{1.98 T}}$ s.

Fig. 11. Flameout characteristics of conical stabilizers o - d_{cT} =
0.03; Δ - 0.04; o - 0.051; ● - 0.025; ∅ - 0.04; ▲ - 0.06; ▱ - 0.05;
▱ - d_{cT} = 0.07-008 s. $\frac{l}{v_n}$ ————. s.

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